CLAIMS

1. A low emittance growth extractor for extracting particles from a particle source to form a charged particle beam, comprising:

a first electrode closest to the plasma source with an aperture through which particles can be extracted to form a beam, the particle source forming a meniscus in the vicinity of the aperture with a substantial electric field at the meniscus;

wherein the beam flows through the aperture of a second electrode with an electric field magnitude in the vicinity of the aperture of the second electrode that is substantially greater than the electric field magnitude at the meniscus; and

wherein the beam flows through the aperture of a third electrode with an electric field magnitude in the vicinity of the aperture of the third electrode that is substantially smaller than the electric field magnitude at the meniscus.

2. The extractor of claim 1 in which the meniscus and an equipotential surface in the vicinity of the third electrode are substantially concentric and the beam produced is a converging or diverging beam.

3. The extractor of claim 1 in which the meniscus and an equipotential surface in the vicinity of the third electrode are substantially parallel and the beam produced is a parallel beam.

4. The extractor of claim 1, where in the vicinity of the aperture of each of at least two electrodes is a substantially equipotential concentric surface.

5. The extractor of claim 1, wherein the beam flows through the aperture of a fourth electrode.

6. The extractor of claim 5, wherein the beam flows through the aperture of a fifth electrode with an electric field magnitude in the vicinity of the aperture of the fifth electrode that is substantially smaller than the electric field magnitude at the meniscus.

7. The extractor of claim 6, wherein potentials applied to the electrodes are determined from a set of boundary conditions applied at concentric surfaces.

8. The extractor of claim 6, where the electric field magnitude in the vicinity of the fifth electrode is substantially zero.

9. The extractor of claim 1, wherein potentials applied to the electrodes are determined from a set of boundary conditions applied at concentric surfaces.

10. The extractor of claim 1, where the electric field magnitude in the vicinity of the third electrode is substantially zero.

11. The extractor of claim 1 wherein the beam has a brightness of greater than 10^5 $A/sr/m^2$.

12. A low emittance growth extractor for extracting particles from a particle source to form a beam, comprising:

a particle source providing a source of particles to form a particle beam;

a first region with an entrance for receiving particles from the source, having a high potential and substantial electric field at its entrance, and a low potential with substantially zero electric field at its exit; and

a second region with the exit of the first region being the entrance to the second region and with the second region having zero potential and substantially zero electric field at its exit; thereby providing a beam having little or no emittance growth as it traverses the extractor.

13. The extractor of claim 12, wherein the electric field in the first region changes monotonically from a substantial value at its entrance to a much higher value between the entrance and the exit and then to substantially zero at its exit.

14. The extractor of claim 12, wherein the electric field in the second region changes monotonically from substantially zero at its entrance to a substantial value between the entrance and the exit and then to substantially zero at its exit.

15. The extractor of claim 14, wherein the electric field in the first region changes monotonically from a substantial value at its entrance to a much higher value between the entrance and the exit and then to substantially zero at its exit.

16. A method of manufacturing a set of electrodes to extract a particle beam from a particle source, comprising:

providing a source of particles to form a particle beam;

providing a sequence of electrodes that exhibit potentials to produce a beam that flows through the apertures of the electrodes with a substantially zero electric field at an exit aperture of the sequence of electrodes.

17. The method of claim 16, wherein the beam exhibits a potential gradient at a second electrode that is substantially greater than the potential gradient at a first electrode closest to the particle source.

18. The method of claim 17, wherein the beam exhibits a potential gradient at a third electrode that is substantially less than the potential gradient at the first electrode.

19. The method of claim 18, wherein the beam exhibits a non-zero potential gradient at a fourth electrode between the third electrode and a fifth electrode and exhibits a substantially zero potential gradient at the fifth electrode.

20. The method of claim 16, wherein the shapes and potentials applied to the electrodes to produce a beam with a small electric field at the exit aperture are determined from a set of boundary conditions applied at concentric surfaces.

21. The method of claim 16, wherein the positions of the electrodes are determined from a set of boundary conditions applied at concentric surfaces.

22. An apparatus for extracting a charged particle beam from a charged particle source, comprising:

a charged particle source;

a first, second and third electrode each with an aperture through which the charged particle beam flows, each exhibiting an electric potential and a shape to produce a beam with substantially concentric equipotential surfaces.

23. The apparatus of claim 22, wherein the potentials of the electrodes produce a beam with a substantially zero electric field in the vicinity of an aperture of an electrode.

24. The apparatus of claim 22, further comprising a fourth electrode exhibiting a potential and a shape so that the combined effect of all the electrodes is to produce a beam that exhibits a substantially zero electric field at an aperture of the fourth electrode.

25. The apparatus of claim 22, further comprising a fourth electrode and a fifth electrode each exhibiting a potential and a shape so that the combined effect of all the electrodes is to produce a beam that exhibits substantially zero electric field at an aperture of the fifth electrode.

26. The apparatus of claim 25, wherein the potential exhibited by the fifth electrode is substantially zero.

27. The apparatus of claim 22, wherein the potentials and positions of the electrodes are determined from a set of boundary conditions applied at concentric surfaces.

28. The apparatus of claim 26, further comprising a fourth electrode with a substantial electric field in the vicinity of its aperture.

29. The apparatus of claim 28, further comprising a fifth electrode with a substantially zero electric field in the vicinity of its aperture.